

Separation Assurance (SA)

The primary purpose of the research on Separation Assurance in the Airspace Operations Laboratory is to gather more insight into the fundamental problem of human/automation integration and allocation of roles and responsibilities required to achieve the significant capacity increases targeted for the Next Generation Air Transportation System (NextGen). Initial part-task studies with controllers in the loop on this research topic have been conducted in the Airspace Operations Laboratory since August 2007. These studies specifically begin to investigate the future role of air traffic controllers and automation in a service provider-based automated separation assurance environment. The focus is on trajectory-based operations at double and triple the traffic density of today's airspace system. **An introduction to this research area is also provided in the movie on effective human/automation cooperation on this website**

Problem

Air traffic demand is anticipated to grow substantially in the coming decades. The Federal Aviation Administration (FAA) and industry forecast that air traffic operations are expected to increase 150 to 250 percent over the next two decades. Analyses of even the most conservative growth estimates show a significant lack of existing and planned capacity.

It is assumed that managing 2 or 3 times today's traffic density requires a fundamental change from today's operations in how separation between aircraft is assured. In today's very safe system, air traffic controllers take active control over each aircraft in their airspace and issue clearances to keep it separate from other traffic, expedite traffic flows, and provide additional services, workload permitting. Being actively involved with each individual aircraft provides the awareness required to detect and resolve potential losses of separation independent of automated aids. However, this manual process can only be performed for a very limited number of aircraft. In recognition of this fact, each airspace sector today has a defined maximum number of aircraft that are allowed to enter. This constraint exists as a way of ensuring that the demands on the cognitive resources of the air traffic controller(s) controlling this sector are not exceeded. Figure 1 below depicts an air traffic controller display contrasting a typical current day high traffic density to twice and three times this density. Assuming that the display on the left represents the limit of the sustained traffic load a controller can comfortably manage today; operations need to change significantly for the move to the traffic levels depicted in the center and on the right to be realized.

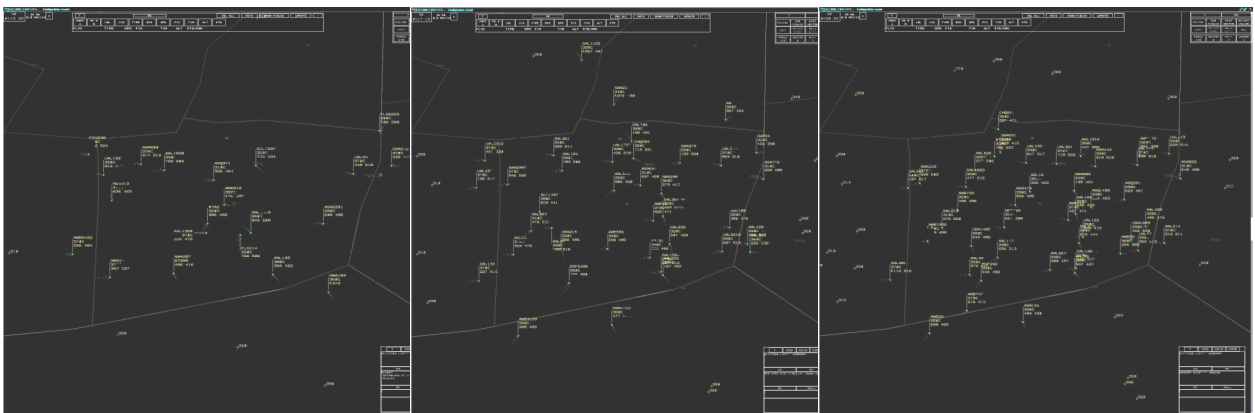


Figure 1: Current day controller display with 1x, 2x and 3x traffic. 2x and 3x cannot be managed with conventional air traffic control techniques.

Approach

NextGen envisions trajectory-based operations (TBO) to replace clearance-based operations in many parts of the airspace. New automated separation assurance functions are intended to help overcome the aforementioned limitations of controllers in manually maintaining safe separation between aircraft. The two primary new separation assurance concepts are airborne self-separation and ground-based automated separation assurance. Research is ongoing in both areas. Between 2002 and 2004, NASA researchers, including the researchers in the AOL were part of human-in-the-loop assessments of mixed operations with airborne self-separation at more than two times today's traffic density.

In late 2006 the AOL team started implementing the latest ground-based conflict resolution technologies developed under the guidance of Heinz Erzberger in NASA Ames' Aviation Systems division. At the same time new display prototypes were developed in the AOL that reflect the shift in roles and responsibilities from the human to the automation and are designed to enable managing the extreme traffic density that is envisioned for NextGen. An example prototype is depicted below for the same traffic situation that can be seen on the 3x display above and on the right.

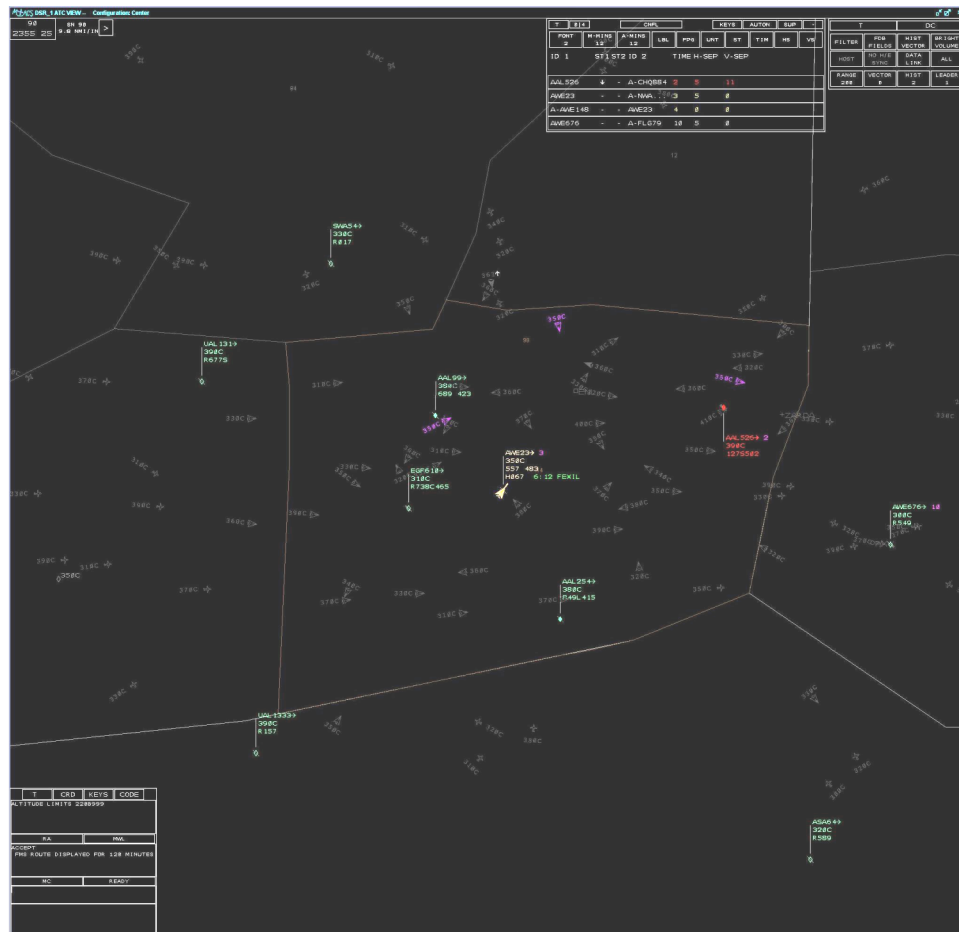


Figure 2: Controller display prototype for managing higher traffic levels with advanced automation. All low-lighted aircraft are managed by the ground-based separation assurance automation. The controller manages the highlighted aircraft in the same airspace.

Today the AOL represents one of the very few -if not the only- laboratory that can simulate the full range of near-, mid- and far-term separation assurance functions from current day air traffic control via integrated decision support functions to fully automated separation assurance. All capabilities are integrated into realistic controller and pilot workstations and can be turned on or off by the researchers via setup panels. The ground automation is fully interoperable with current day and advanced flight decks that participate in the simulation within the AOL or simulation facilities that are networked with the AOL.

Experiments

Controller and pilot in-the-loop simulations with ground-based separation assurance automation in double and triple traffic densities have been breaking new ground and represent a first step towards understanding some of the complexities of human/automation interaction in the airspace system of 2025 and beyond. Three controller-in-the loop experiments on Separation Assurance have been conducted in the AOL between August 2007 and July 2008.

Study1: Levels of Automation

The first study focused on identifying the appropriate level of automation for a given traffic density. It was found that interactive decision support with automated conflict resolution advisories can result in adequate workload for 2x, but 3x would require even more automated operations to be manageable. The automated resolutions suggested to the participants in the interactive mode were rated as highly acceptable.

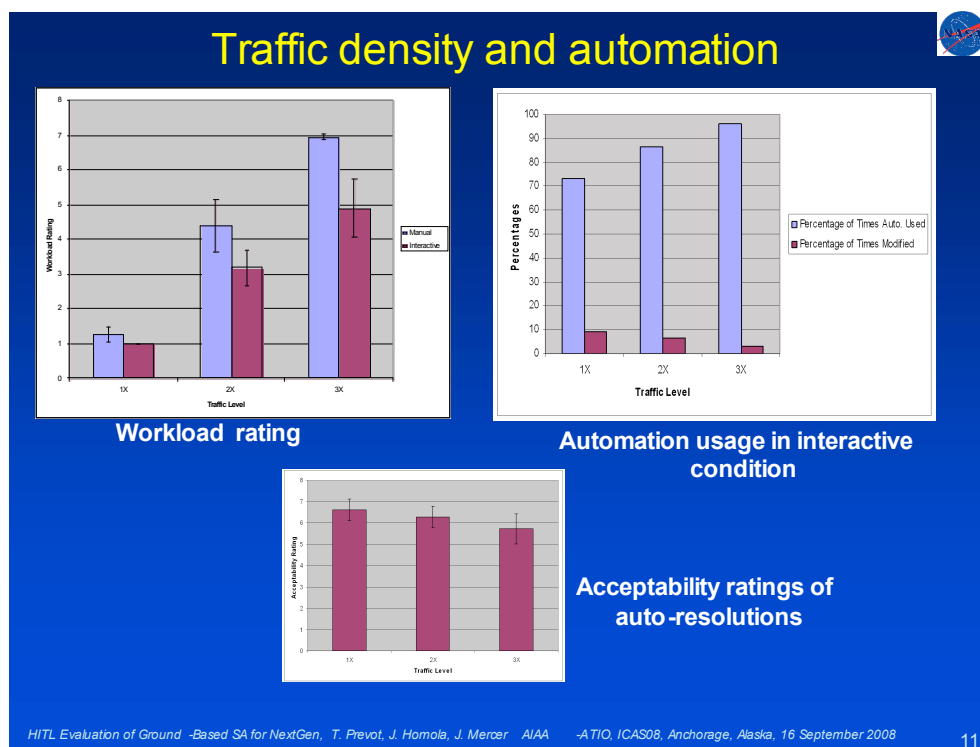


Figure 3: Workload and acceptability of CD&R technologies by Level of Automation and Traffic Density (Homola (2008), Prevot, Homola and Mercer (2008))

Study 2: Effects of Mixed Operations on Airspace Configuration

The second experiment investigated the effects of Mixed Operations on Airspace Configuration and was conducted as part of the Dynamic Airspace Configuration (DAC) research. Initial findings indicate that a limited number of IFR aircraft may be manually controlled in the same airspace as a potentially large number of aircraft that is controlled by a different entity –the ground automation in this case. At the same time the workload ratings for the IFR only runs indicate that the availability of conflict detection and resolution tools does not seem to enable a significant capacity increase if the controller has to issue verbal control instructions and maintain awareness of the traffic similar to the way it is done today.

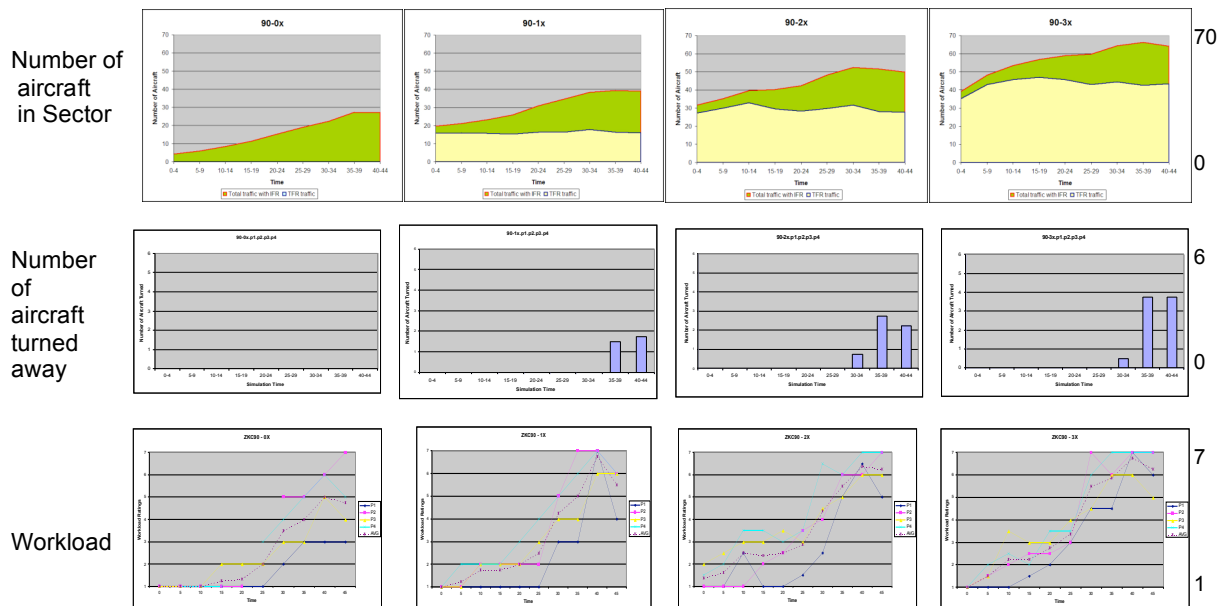


Figure 4. Number of aircraft in sector, number of aircraft turned away and controller workload in Sector 90 (Prevot, Homola and Mercer (2008))

Study 3: Off-nominal situations in automated operations

The third simulation investigated off-nominal situations in automated operations. In this latest experiment six professional controllers in the AOL and twenty airline pilots participated in NASA Ames' Flight Deck Display Research Laboratory. Controllers and pilots used new display concepts and technologies to manage dramatically increased (2x and 3x) traffic demand through a complex airspace sector in Indianapolis Center under routine and off-nominal conditions. Advanced conflict detection and resolution software monitored all aircraft for potential problems and automatically data linked new trajectories to solve medium-term conflicts. In urgent situations a tactical conflict resolution function generated heading changes that were delivered to the flight crews via speech synthesis. Air traffic controllers and pilots supervised the automated operations and used advanced features to handle pilot requests, system failures and emergency situations. Although presented with many scripted off-nominal situations the participants found the concept highly promising and commented on the need for such technologies and operations to achieve the required capacity increase.

Compared to current -day operations, what are the advantages you see (if any) to the concept you just experienced?	Compared to current -day operations, what are the disadvantages you see (if any) to the concept you just experienced?
1 (Retired) Big advantage, the system would be safer and more efficient.	
2 (Retired) Ability to work more planes.	Computer failure, controllers lose proficiency.
3 (Active) Current conditions are almost maxed out with current capabilities. New means of working traffic are needed to allow for growth in system.	Less time to see and react to potentially dangerous situations. At times controllers must react and might not necessarily have all needed info available.
4 (Active) More traffic can be safely worked by fewer people with greater efficiency.	None except a few bruised ego's both current pilot's and controllers.
5 (Active) Huge advantages - Datalink frees up so much time all by itself. Automated conflict resolution is the only way the system can handle this type of increased workload. Something else that must be considered is reduced separation minima. Demonstrate that it can be done safely and efficiently and that will only increase the relevance and value of this concept.	Loss of situational awareness. Having to solve imminent situations was very challenging.
6 (Retired) Larger volume of TFC and less human errors.	A lot of other human factors have to come into play also weather and TFC management and the airlines/pilots.

Figure 5. Participant comments from post simulation questionnaire after study on off-nominal situations in automated operations

The findings from these experiments will be instrumental in further defining the technology requirements and roles and responsibilities for separation assurance in the Next Generation Air Transportation System.

Publications:

Homola, J. (2008) Analysis of Human and Automated Separation Assurance at Varying Traffic Levels. Master's thesis, San Jose State University, San Jose, California

P. Kopardekar, T. Prevot and M. Jastrezebski (2008) "Complexity Measurement Under Higher Levels of Automation and Higher Traffic Densities" Air Traffic Control Quarterly (in preparation)

Prevot, T., Homola J. and J. Mercer (2008) "Initial Study of Controller/Automation Integration for NextGen Separation Assurance" AIAA-2008-6330 AIAA Guidance, Navigation, and Control Conference and Exhibit 18 - 21 August 2008, Honolulu, Hawaii

Prevot, T., Homola J. and J. Mercer (2008) "Human-in-the-Loop Evaluation of Ground-Based Automated Separation Assurance for NextGen" ICAS 2008-11.4.5, 6th International Congress of the Aeronautical Sciences (ICAS), and AIAA-ATIO-2008-8885, Anchorage, Alaska, Sept 15-19, 2008

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